UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Chemical analyses of lignite from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Montana, and Golden Valley County, North Dakota

by

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Open-File Report 80-179
1980

INTRODUCTION

As part of a continuing program by the U.S. Geological Survey to collect and chemically analyze representative samples of U.S. coals, 57 lignite samples were collected from 27 core holes in the Paleocene Fort Union Formation in northeastern Montana and western North Dakota (fig. 1). Analytical data obtained from these samples are summarized in this report. Four core holes (nine lignite samples) are from McCone County, Montana; three core holes (seven lignite samples) are from Richland County, Montana; four core holes (eight lignite samples) are from Dawson County, Montana; ten core holes (20 lignite samples) are from Wibaux County, Montana; and six core holes (13 lignite samples) are from Golden Valley County, North Dakota. The 57 samples are listed in table 1 and the locations of the core holes are shown in figure 2. Geophysical and lithologic logs for all US-75 core holes are in U.S. Geological Survey and Montana Bureau of Mines and Geology (1976); for all US-76 core holes, U.S. Geological Survey and Montana Bureau of Mines and Geology (1977); and for all WB-77 core holes, Harksen (1978).

EXPLANATION OF TABLES

Proximate and ultimate analyses, heat-of-combustion, air-dried-loss, forms-of-sulfur, and ash-fusion-temperature determinations on 55 single and composite lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Montana, and Golden Valley County, North Dakota are listed in table 2. These analyses were provided by the U.S. Department of Energy, Pittsburgh, Pa. Analyses for ash content and 35 major and minor oxides and trace elements in the laboratory ash (table 3) and analyses of nine trace elements in whole lignite (table 4) for all 57 samples were provided by the U.S. Geological Survey, Denver, Colo. Analytical procedures used by the U.S. Geological Survey are described in Swanson and Huffman (1976).

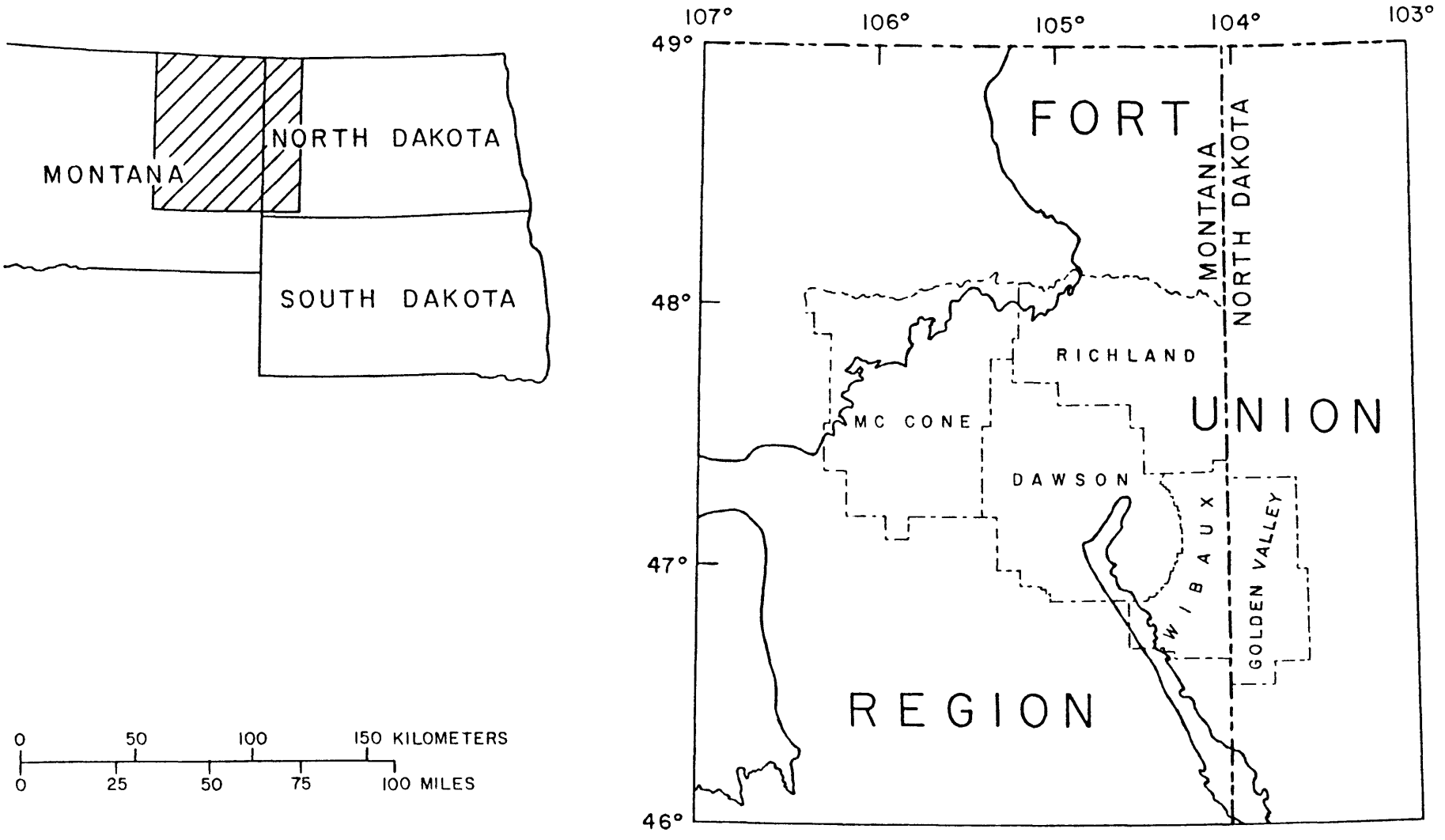

Figure 1.--Map of northeastern Montana and western North Dakota showing locations of McCone, Richland, Dawson, and Wibaux Counties, Montana, and Golden Valley County, North Dakota, and an outline of the Fort Union coal region. Map modified from Averitt (1942).

Table 1.--U.S. Geological Survey sample numbers, core-hole numbers, index map locations, core-hole locations, and depth intervals represented for 57 lignite samples from the Paleocene Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.

[All samples are from cores. One meter = 3.28 feet. The first two digits in the USGS core-hole numbers indicates year drilled]

USGS sample number	USGS core-hole number	Index map location	Core hole location	Depth interval represented in meters
			McCone County, Mont.	
D188118	US-762	1	SE 1/4 NE 1/4 sec. 26, T. 21 N., R. 45 E.	23.8-25.3
D188119	---do---	1	---------do---------	25.3-26.8
D188120	---do---	1	---------do---------	26.8-28.2
D188121	US-768	25	NW 1/4 NE 1/4 sec. 2, T. 20 N., R. 45 E.	56.4-59.4
D188122	---do---	25	---------do---------	59.4-61.7
D188123	US-7616	2	SE 1/4 SE 1/4 sec. 20, T. 20 N., R. 45 E.	29.3-32.2
D188124	---do---	2	---------do---------	32.2-34.1
D188125	US-7617	26	NE 1/4 SE 1/4 sec. 30, T. 20 N., R. 45 E.	9.7-12.7
D188126	---do---	26	---------do---------	12.7-15.6
			Richland County, Mont.	
D188136	US-75119	3	NE 1/4 SW 1/4 sec. 30, T. 22 N., R. 54 E.	28.7-30.9
D188137	---do---	3	---------do---------	30.9-31.7
D188138	US-76113	4	SW 1/4 SE 1/4 sec. 22, T. 20 N., R. 59 E.	33.5-35.4
D188140	US-7695	27	SW 1/4 SE 1/4 sec. 4, T. 20 N., R. 59 E.	45.7-46.0
D188141	---do---	27	---------do---------	46.2-50.8
D188142	---do---	27	---------do---------	66.4-67.4
D188143	---do---	27	---------do---------	67.4-68.7
			Dawson County, Mont.	
D188128	US-75104	5	NE 1/4 SE 1/4 sec. 8, T. 21 N., R. 53 E.	11.0-13.4
D188129	US-75106	6	SE 1/4 SE 1/4 sec. 24, T. 20 N., R. 52 E.	20.1-22.6
D188130	---do---	6	---------do---------	22.6-25.0
D188131	US-75108	7	SW 1/4 SE 1/4 sec. 1, T. 20 N., R. 54 E.	53.9-56.4
D188132	---do---	7	---------do---------	56.4-58.9
D188133	---do---	7	---------do---------	58.9-61.4
D188134	---do---	7	---------do---------	61.4-64.2
D188135	US-7597	8	NE 1/4 NE 1/4 sec. 14, T. 21 N., R. 55 E.	20.7-22.6
			Wibaux County, Mont.	
D188144	US-76116	9	NW 1/4 NW 1/4 sec. 18, T. 18 N., R. 59 E.	18.8-20.1
D188145	---do---	9	---------do---------	45.7-48.2
D196641	WB-7783	10	NE 1/4 NE 1/4 sec. 2, T. 15 N., R. 59 E.	13.1-14.3
D196642	---do---	10	---------do---------	14.3-14.9
D196643	---do---	10	---------do---------	22.6-26.8
D196645	WB-7740	11	SW 1/4 SW 1/4 sec. 14, T. 14 N., R. 60 E.	14.0-19.5
D196647	---do---	11	---------do---------	33.2-34.7
D196648	---do---	11	---------do---------	35.5-36.8
D196649	---do---	11	---------do---------	37.0-37.2

Table 1.--U.S. Geological Survey sample numbers, core-hole numbers, index map locations, core-hole locations, and depth intervals represented for 57 lignite samples from the Paleocene Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

USGS sample number	USGS core-hole number	Index map location	Core hole location	Depth interval represented in meters
			Wibaux County, Mont. (cont.)	
D196650	WB-7731	12	SE 1/4 NW 1/4 sec. 10, T. 13 N., R. 60 E.	30.8-40.2
D196651	---do---	12	----------do----------	40.5-41.1
D196652	WB-7787	13	NE 1/4 SE 1/4 sec. 34, T. 16 N., R. 59 E.	73.2-75.9
D196653	WB-7736	14	NW 1/4 SW 1/4 sec. 34, T. 14 N., R. 60 E.	16.4-29.2
D196654	---do---	14	----------do----------	29.2-29.5
D196655	WB-7758	15	SW 1/4 SW 1/4 sec. 26, T. 15 N., R. 60 E.	17.7-22.1
D196657	---do---	15	----------do----------	25.0-28.9
D196658	WB-776	16	NE 1/4 NE 1/4 sec. 20, T. 12 N., R. 61 E.	14.1-14.7
D196659	---do---	16	----------do----------	16.6-19.4
D196661	WB-7763	17	NW 1/4 SW 1/4 sec. 20, T. 15 N., R. 60 E.	15.6-17.0
D196662	WB-7785	18	SW 1/4 SE 1/4 sec. 6, T. 15 N., R. 60 E.	23.8-26.1
			Golden Valley County, N. Dak.	
D196624	WB-773	19	SE 1/4 SE 1/4 sec. 10, T. 138 N., R. 106 W.	14.5-14.8
D196625	---do---	19	----------do----------	22.7-26.2
D196627	WB-77104	20	NE 1/4 NW 1/4 sec. 10, T. 138 N., R. 106 W.	14.9-15.5
D196628	---do---	20	----------do----------	17.7-21.0
D196629	WB-7755	21	NW 1/4 NW 1/4 sec. 20, T. 141 N., R. 105 W.	10.7-12.3
D196630	---do---	21	----------do----------	14.5-14.8
D196631	---do---	21	NW 1/4 NE 1/4 sec. 20, T. 141 N., R. 105 W.	23.4-24.0
D196632	---do---	21	----------do----------	28.0-34.4
D196634	---do---	21	----------do----------	36.3-36.5
D196635	WB-77107	22	SE 1/4 SE 1/4 sec. 20, T. 141 N., R. 105 W.	44.8-52.1
D196637	WB-7714	23	NE 1/4 NW 1/4 sec. 34, T. 139 N., R. 106 W.	15.2-17.7
D196638	---do---	23	----------do----------	17.7-22.3
D196640	Wb-7724	24	NE 1/4 NW 1/4 sec. 22, T. 139 N., R. 106 W.	13.3-19.8

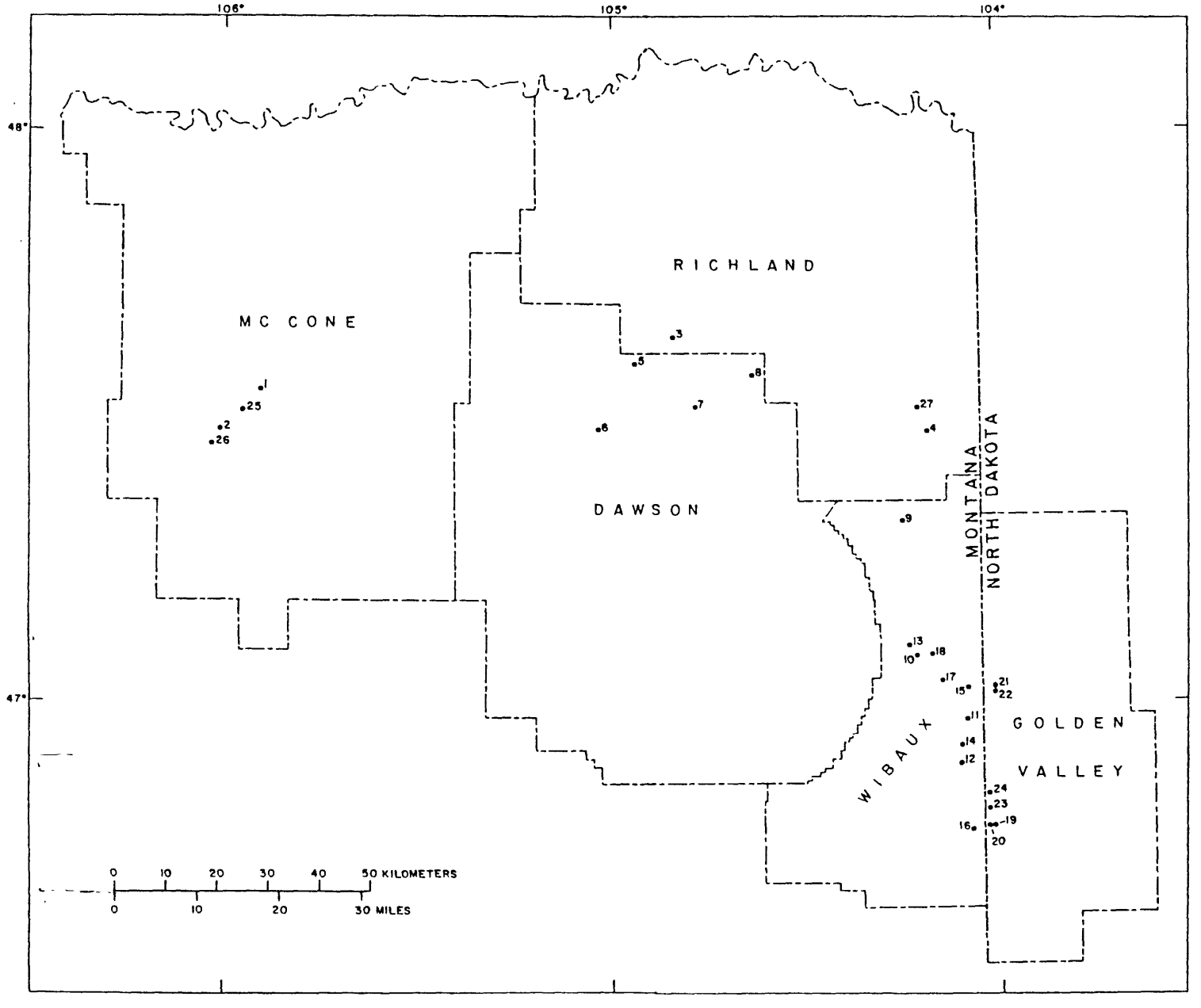

Figure 2.--Index map showing core hole locations in McCone, Richland, Dawson, and Wibaux Counties, Montana, and Golden Valley County, North Dakota. Detailed location descriptions are in table 1.

Table 5 contains the data listed in table 3 converted to a whole-lignite basis plus for completeness, the whole-lignite analyses listed in table 4. Twenty-four additional elements not listed in tables 3, 4, and 5 were looked for but not found in amounts greater than their lower limits of detection (table 6). Unweighted statistical summaries of analytical data in tables 2, 3, and 5 are listed in tables 7, 8, and 9. For comparison, data summaries for 32 other Fort Union region lignite samples (table 7) and 80 other Fort Union region lignite samples (tables 8 and 9) are included. Statistical summaries for P_2O_5 contents in lignite ash and Ag, Cd, Ge, and La contents in whole lignite were not included in tables 7 and 9 because these variables were detected in an insufficient number of samples to calculate meaningful statistics.

P_2O_5 contents for all samples were determined by X-ray-fluorescence spectroscopy. However, due to a change in technique the lower detection limit for samples D188118-D188126, D188128-D188138, and D188140-D188145 is 1.0 percent in ash; for the other 31 samples it is 0.01 percent in whole coal.

To be consistent with the precision of the semiquantitative emission spectrographic technique, arithmetic and geometric means of elements determined by this method are reported as the midpoint of the enclosing six-step brackets (see headnote of table 3, or Swanson and Huffman, 1976, p. 6 for an explanation of six-step brackets.)

EXPLANATION OF STATISTICAL TERMS USED IN SUMMARY TABLES

In this report the geometric mean (GM) is used as the estimate of the most probable concentration (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithm of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard deviation of the

logarithms of the analytical values. These statistics are used because the quantities of trace elements in natural materials commonly exhibit positively skewed frequency distributions; such distributions are normalized by analyzing and summarizing trace-element data on a logarithmic basis.

If the frequency distributions are lognormal, the geometric mean is the best estimate of the mode, and the estimated range of the central two-thirds of the observed distribution has a lower limit equal to GM/GD and an upper limit equal to GM·GD. The estimated range of the central 95 percent of the observed distribution has a lower limit equal to GM/GD^2 and an upper limit equal to $GM \cdot GD^2$ (Connor and others, 1976).

Although the geometric mean is, in general, an adequate estimate of the most common analytical value, it is, nevertheless, a biased estimate of the arithmetic mean. The estimates of the arithmetic means listed in the summary tables are Sichel's $\underline{t}$ statistic (Miesch, 1967).

A common problem in statistical summaries of trace-element data arises when the element content of one or more of the samples is below the limit of analytical detection. This results in a "censored" distribution. Procedures developed by Cohen (1959) were used to compute unbiased estimates of the geometric mean, geometric deviation, and arithmetic mean when the data are censored.

DISCUSSION

The apparent ranks of all 55 single and composite lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Montana, and Golden Valley County, North Dakota were calculated using the data in table 2 and the formulas in ASTM designation D-388-77 (American Society for Testing and Materials, 1978). The apparent ranks of these samples range from lignite B (two samples) to lignite A (53 samples)

A statistical comparison (Student's t test, 95-percent confidence level) of the geometric mean contents of the U.S. Department of Energy data for 55 lignite core samples from the Fort Union Formation listed in this report with means for 32 other Fort Union region lignite samples from mines (Swanson, Huffman, and Hamilton, 1974) shows that the lignite core samples have significantly higher contents of moisture, ash, sulfate and pyritic sulfur, significantly lower contents of volatile matter, fixed carbon, and carbon, and a significantly lower heat of combustion. The contents of hydrogen, nitrogen, oxygen, total sulfur, and organic sulfur are not significantly different. When compared at the 99-percent confidence level the contents of moisture, fixed carbon, sulfate and pyritic sulfur are not significantly different.

A statistical comparison of the geometric mean contents of ash and contents of nine major and minor oxides in the ash from 57 lignite core samples listed in this report with means for 80 other Fort Union region mine and core lignite samples listed in Hatch and Swanson (1977) shows that the lignite core samples have significantly higher ash contents, higher SiO_2, K_2O, Fe_2O_3 and TiO_2 contents in the ash, and significantly lower CaO, MgO, and SO_3 contents in the ash. The contents of Al_2O_3 and Na_2O in ash are not significantly different. When compared at the 99-percent confidence level the contents of Fe_2O_3 and TiO_2 in ash are not significantly different.

A statistical comparison of the geometric means of the contents of 35 elements in 57 lignite core samples listed in this report with means for 80 other Fort Union region mine and core samples listed in Hatch and Swanson (1977) shows that the lignite core samples have significantly higher contents of Si, Al, Mg, K, Fe, Ti, As, Be, Cu, F, Ga, Li, Mn, Mo, Ni, Sb, U, V, Y, Yb, Zn, and Zr and significantly lower contents of Ba, Co, Cr, Sr, and Th. The contents of Ca, Na, B, Hg, Nb, Pb, Sc, and Se are not significantly

different. When compared at the 99-percent confidence level the contents of As, Ba, F, Ni, and Th are not significantly different.

Differences in the oxide composition of lignite ashes and the elemental contents of lignite result from differences in the total and relative amounts of the various inorganic minerals, the elemental composition of these minerals, and the total and relative amounts of any organically bound elements. The chemical form and distribution of a given element are dependent on the geologic history of the lignite bed. A partial listing of the factors that influence element distributions would include chemical composition of original plants; amounts and compositions of the various detrital, diagenetic, and epigenetic minerals; chemical characteristics of the ground waters that come in contact with the bed; temperatures and pressures during burial; and extent of weathering. No evaluation of these factors has been made for any of the Fort Union Formation lignite samples listed in this report.

Compared to other U.S. coals (Swanson and others, 1976; Hatch and Swanson, 1977), Fort Union Formation lignites are characterized by relatively low ash, low sulfur, low heat of combustion, and a high moisture content. The contents of elements of environmental concern such as As, Be, Hg, Mo, Sb, and Se are low in Fort Union Formation lignite when compared to most other U.S. coals.

ACKNOWLEDGMENTS

Fundamental to this paper is the contribution of the team of chemical laboratory personnel in the U.S. Geological Survey under the direction of Claude Huffman, Jr. and Joseph H. Christie: James W. Baker, Ardith J. Bartel, Candy Bliss, Nancy M. Conklin, James G. Crock, Celeste M. Ellis, Patricia G. Guest, John C. Hamilton, Raymond G. Havens, Roy J. Knight, Cindy McFee, Violet M. Merritt, Hugh T. Millard, Jr., Harriet G. Neiman, George O. Riddle, Gaylord D. Shipley, Vertie C. Smith, James A. Thomas, Michele L. Tuttle, Richard E. VanLoenen, James S. Wahlberg. In connection with the acknowledgment to the above staff of chemical analysts, the invaluable contribution of the chemists in the Coal Analysis Section (Forrest E. Walker, Chemist in Charge), U.S. Department of Energy, Pittsburgh, Pa., is also gratefully acknowledged. We also appreciate Rick T. Hildebrand's help in preparing the data tables and Betty L. Arnone's drafting of the illustrations.

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Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.

[All analyses in percent except heat of combustion and ash-fusion temperatures. For each sample number, the analyses are reported three ways: First, as received; second, moisture free; and third, moisture and ash free. Kcal/kg = 0.556 (Btu/lb); $^{o}F = (^{o}C \times 1.8) + 32$; L, less than the value shown, B, not determined. Sample D188118* is a composite of samples D188118 and D188119; D188142* is a composite of D188142 and D188143.]

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D188118*	36.4	25.1	31.2	7.3	6.4	40.1	0.6	45.3	0.3	3,670	6,600
	---	39.5	49.1	11.5	3.7	63.1	.9	20.4	.5	5,770	10,390
	---	44.6	55.4	---	4.2	71.2	1.1	23.0	.5	6,520	11,730
D188120	38.1	24.8	31.0	6.1	6.6	39.7	.6	46.9	.2	3,620	6,520
	---	40.1	50.1	9.9	3.8	64.1	1.0	21.1	.3	5,860	10,540
	---	44.4	55.6	---	4.2	71.1	1.1	23.4	.4	6,500	11,690
D188121	37.2	13.3	44.0	5.5	6.6	41.5	.6	45.4	.4	3,800	6,840
	---	21.2	70.1	8.8	3.9	66.1	1.0	19.6	.6	6,050	10,890
	---	23.2	76.8	---	4.3	72.4	1.0	21.5	.7	6,630	11,940
D188122	38.0	15.1	41.3	5.6	6.5	40.7	.6	46.5	.2	3,720	6,690
	---	24.4	66.6	9.0	3.7	65.6	1.0	20.5	.3	6,000	10,790
	---	26.8	73.2	---	4.0	72.2	1.1	22.6	.4	6,590	11,860
D188123	34.9	15.8	39.7	9.6	6.6	40.0	.6	42.3	.8	3,680	6,620
	---	24.3	61.0	14.7	4.2	61.4	.9	17.3	1.2	5,650	10,180
	---	28.5	71.5	---	4.9	72.1	1.1	20.3	1.4	6,630	11,940
D188124	35.5	16.0	41.1	7.4	6.6	41.4	.6	42.9	1.0	3,860	6,940
	---	24.8	63.7	11.5	4.1	64.2	.9	17.6	1.6	5,980	10,760
	---	28.0	72.0	---	4.7	72.5	1.1	19.9	1.8	6,750	12,160
D188125	42.4	24.6	29.4	3.6	6.7	37.3	.6	51.5	.2	3,260	5,880
	---	42.7	51.0	6.2	3.5	64.8	1.0	24.0	.3	5,670	10,200
	---	45.6	54.4	---	3.7	69.1	1.1	25.6	.4	6,050	10,880
D188126	37.1	16.2	42.5	4.2	6.8	41.9	.6	46.3	.2	3,860	6,950
	---	25.8	67.6	6.7	4.3	66.6	1.0	21.2	.3	6,140	11,050
	---	27.6	72.4	---	4.6	71.4	1.0	22.7	.3	6,580	11,840
D188136	39.6	25.3	25.9	9.3	B	B	B	B	1.0	3,270	5,890
	---	41.9	42.9	15.4	B	B	B	B	1.7	5,420	9,760
	---	49.5	50.7	---	B	B	B	B	2.0	6,410	11,530
D188137	40.6	26.5	28.0	4.9	B	B	B	B	.3	3,420	6,150
	---	44.6	47.1	8.2	B	B	B	B	.5	5,760	10,360
	---	48.6	51.4	---	B	B	B	B	.6	6,270	11,290
D188138	41.0	27.0	25.1	6.9	7.1	36.9	.7	47.8	.6	3,430	6,170
	---	45.8	42.5	11.7	4.3	62.5	1.2	19.2	1.0	5,810	10,450
	---	51.8	48.2	---	4.9	70.8	1.3	21.8	1.2	6,580	11,840
D188140	37.9	26.6	27.4	8.1	6.9	38.8	.6	44.6	1.0	3,690	6,640
	---	42.8	44.1	13.0	4.3	62.5	1.0	17.6	1.6	5,940	10,700
	---	49.3	50.7	---	5.0	71.9	1.1	20.2	1.9	6,830	12,300

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Air-dried loss	Forms of sulfur			Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic	Initial deformation	Softening	Fluid
D188118*	24.8	0.01	0.04	0.23	1,265	1,320	1,370
	---	.02	.06	.36			
	---	.02	.07	.41			
D188120	28.1	.01	.04	.17	1,285	1,330	1,380
	---	.02	.06	.27			
	---	.02	.07	.30			
D188121	25.8	.01	.06	.29	1,235	1,290	1,340
	---	.02	.10	.46			
	---	.02	.10	.51			
D188122	28.2	.00	.04	.13	1,205	1,255	1,320
	---	.00	.06	.21			
	---	.00	.07	.23			
D188123	24.3	.01L	.25	.55	1,095	1,155	1,205
	---	.02L	.38	.84			
	---	.02L	.45	.99			
D188124	25.5	.01	.41	.63	1,180	1,230	1,290
	---	.02	.64	.98			
	---	.02	.72	1.10			
D188125	27.9	.01	.06	.15	1,415	1,465	1,520
	---	.02	.10	.26			
	---	.02	.11	.28			
D188126	27.0	.01	.04	.20	1,290	1,345	1,395
	---	.02	.06	.32			
	---	.02	.07	.34			
D188136	36.2	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188137	37.1	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188138	29.7	.01	.09	.48	1,075	1,130	1,190
	---	.02	.15	.81			
	---	.02	.17	.92			
D188140	28.5	.01	.10	.89	1,075	1,125	1,180
	---	.02	.16	1.43			
	---	.02	.19	1.65			

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D188141	41.9	23.6	28.7	5.8	6.9	37.8	0.6	48.4	0.4	3,470	6,240
	---	40.6	49.4	10.0	3.9	65.1	1.0	19.2	.7	5,970	10,740
	---	45.1	54.9	---	4.3	72.3	1.1	21.3	.8	6,630	11,930
D188142*	36.0	26.8	30.9	6.3	6.9	41.3	.7	44.4	.3	3,830	6,890
	---	41.9	48.3	9.8	4.5	64.5	1.1	19.4	.5	5,980	10,760
	---	46.4	53.6	---	5.0	71.6	1.2	21.5	.5	6,630	11,940
D188128	39.3	26.0	26.8	7.9	B	B	B	B	.9	3,330	5,990
	---	42.8	44.2	13.0	B	B	B	B	1.5	5,480	9,870
	---	49.2	50.8	---	B	B	B	B	1.7	6,300	11,340
D188129	38.1	27.5	26.8	7.5	B	B	B	B	.8	3,510	6,310
	---	44.4	43.3	12.1	B	B	B	B	1.3	5,660	10,200
	---	50.6	49.3	---	B	B	B	B	1.5	6,450	11,600
D188130	38.4	30.0	23.1	8.5	B	B	B	B	.5	3,380	6,080
	---	48.7	37.5	13.8	B	B	B	B	.8	5,490	9,870
	---	56.5	43.5	---	B	B	B	B	.9	6,360	11,460
D188131	40.4	25.8	28.8	5.0	B	B	B	B	.3	3,420	6,160
	---	43.3	48.3	8.4	B	B	B	B	.5	5,740	10,340
	---	47.3	52.7	---	B	B	B	B	.5	6,270	11,290
D188132	37.0	27.3	29.4	6.3	B	B	B	B	.5	3,610	6,490
	---	43.3	46.7	10.0	B	B	B	B	.8	5,720	10,300
	---	48.1	51.9	---	B	B	B	B	.9	6,360	11,450
D188133	36.4	26.5	27.6	9.6	B	B	B	B	.3	3,380	6,090
	---	41.7	43.4	15.1	B	B	B	B	.5	5,320	9,580
	---	49.1	51.1	---	B	B	B	B	.6	6,270	11,280
D188134	36.6	26.3	26.6	11.6	B	B	B	B	.4	3,340	6,010
	---	41.5	42.0	18.3	B	B	B	B	.6	5,260	9,480
	---	50.8	51.4	---	B	B	B	B	.8	6,440	11,600
D188135	39.6	26.6	26.0	7.8	B	B	B	B	1.5	3,440	6,190
	---	44.0	43.0	12.9	B	B	B	B	2.5	5,690	10,250
	---	50.6	49.4	---	B	B	B	B	2.9	6,540	11,770
D188144	39.6	27.0	27.0	6.4	7.2	38.5	.7	46.9	.3	3,610	6,490
	---	44.7	44.7	10.6	4.6	63.7	1.2	19.4	.5	5,970	10,750
	---	50.0	50.0	---	5.2	71.3	1.3	21.7	.6	6,680	12,030
D188145	37.9	24.4	26.7	11.0	6.7	37.0	.6	42.8	1.8	3,500	6,290
	---	39.3	43.0	17.7	4.0	59.6	1.0	14.7	2.9	5,630	10,140
	---	47.7	52.3	---	4.9	72.4	1.2	17.8	3.5	6,840	12,320

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Air-dried loss	Forms of sulfur			Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic	Initial deformation	Softening	Fluid
D188141	29.7	0.01	0.06	0.33	1,155	1,205	1,255
	---	.02	.10	.57			
	---	.02	.11	.63			
D188142*	25.5	.01	.06	.25	1,130	1,180	1,235
	---	.02	.09	.39			
	---	.02	.10	.43			
D188128	35.5	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188129	34.2	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188130	34.7	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188131	36.7	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188132	33.3	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188133	33.0	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188134	32.1	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188135	36.2	B	B	B	B	B	B
	---	B	B	B			
	---	B	B	B			
D188144	27.1	.01	.06	.27	1,175	1,235	1,285
	---	.02	.10	.45			
	---	.02	.11	.50			
D188145	28.6	.01	1.49	.32	1,155	1,205	1,265
	---	.02	2.40	.52			
	---	.02	2.92	.63			

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D196641	38.6	27.1	26.3	8.0	7.0	37.4	0.7	45.8	1.1	3,500	6,300
	---	44.1	42.8	13.0	4.4	60.9	1.1	18.7	1.8	5,700	10,260
	---	50.7	49.3	---	5.1	70.0	1.3	21.5	2.1	6,560	11,800
D196642	36.5	27.9	26.2	9.4	6.8	34.3	.7	44.8	4.0	3,240	5,840
	---	43.9	41.3	14.8	4.3	54.0	1.1	19.5	6.3	5,110	9,200
	---	51.6	48.4	---	5.1	63.4	1.3	22.8	7.4	6,000	10,790
D196643	36.4	26.5	26.8	10.3	6.8	37.5	.6	43.8	.9	3,440	6,200
	---	41.7	42.1	16.2	4.3	59.0	.9	18.0	1.4	5,420	9,750
	---	49.7	50.3	---	5.2	70.4	1.1	21.5	1.7	6,460	11,630
D196645	37.9	24.6	25.8	11.7	6.6	35.5	.4	44.6	1.2	3,260	5,870
	---	39.6	41.5	18.8	3.8	57.2	.6	17.6	1.9	5,250	9,450
	---	48.8	51.2	---	4.7	70.4	.8	21.6	2.4	6,470	11,640
D196647	36.8	24.6	25.3	13.3	6.3	33.8	.5	42.6	3.5	3,200	5,770
	---	38.9	40.0	21.0	3.5	53.5	.8	15.6	5.5	5,070	9,120
	---	49.3	50.7	---	4.4	67.7	1.0	19.8	7.0	6,420	11,560
D196648	39.1	25.8	27.1	8.0	6.9	37.4	.6	46.2	1.0	3,480	6,270
	---	42.4	44.5	13.1	4.2	61.4	1.0	18.8	1.6	5,720	10,290
	---	48.8	51.2	---	4.8	70.7	1.1	21.6	1.9	6,580	11,850
D196649	26.3	26.6	23.4	23.7	5.2	29.2	.5	29.7	11.7	2,960	5,330
	---	36.1	31.8	32.2	3.1	39.6	.7	8.6	15.9	4,020	7,230
	---	53.2	46.8	---	4.6	58.4	1.0	12.6	23.4	5,920	10,660
D196650	39.1	25.6	27.9	7.4	6.7	37.9	.5	46.7	.7	3,460	6,220
	---	42.0	45.8	12.2	3.9	62.2	.8	19.6	1.1	5,670	10,210
	---	47.9	52.1	---	4.4	70.8	.9	22.3	1.3	6,460	11,620
D196651	33.1	22.8	20.5	23.6	5.9	28.6	.4	39.4	2.1	2,690	4,840
	---	34.1	30.6	35.3	3.3	42.8	.6	14.9	3.1	4,020	7,230
	---	52.7	47.3	---	5.1	66.1	.9	23.0	4.8	6,200	11,170
D196652	33.4	24.6	29.1	12.9	6.1	38.3	.6	41.7	.3	3,440	6,200
	---	36.9	43.7	19.4	3.6	57.5	.9	18.0	.5	5,170	9,300
	---	45.8	54.2	---	4.4	71.3	1.1	22.4	.6	6,410	11,540
D196653	37.3	26.4	27.4	8.9	6.8	38.5	.5	44.4	.9	3,550	6,390
	---	42.1	43.7	14.2	4.2	61.4	.8	17.9	1.4	5,660	10,190
	---	49.1	50.9	---	4.9	71.6	.9	20.9	1.7	6,600	11,880
D196654	35.9	24.5	22.8	16.8	6.6	33.0	.5	41.9	1.1	3,120	5,610
	---	38.2	35.6	26.2	4.1	51.5	.8	15.6	1.7	4,860	8,750
	---	51.8	48.2	---	5.5	69.8	1.1	21.1	2.3	6,590	11,860

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Air-dried loss	Forms of sulfur			Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic	Initial deformation	Softening	Fluid
D196641	24.4	0.09	0.42	0.55	1,200	1,215	1,230
	---	.15	.68	.90			
	---	.17	.79	1.03			
D196642	25.1	.95	1.41	1.63	1,250	1,275	1,345
	---	1.50	2.22	2.57			
	---	1.76	2.61	3.01			
D196643	24.5	.09	.45	.41	1,325	1,375	1,590
	---	.14	.71	.64			
	---	.17	.84	.77			
D196645	26.5	.10	.71	.40	1,100	1,120	1;190
	---	.16	1.14	.64			
	---	.20	1.41	.79			
D196647	24.6	.41	2.34	.70	1,045	1,060	1,075
	---	.65	3.70	1.11			
	---	.82	4.69	1.40			
D196648	25.6	.05	.38	.54	1,180	1,200	1,215
	---	.08	.62	.89			
	---	.09	.72	1.02			
D196649	16.1	.82	8.40	2.46	1,215	1,230	1,250
	---	1.11	11.40	3.34			
	---	1.64	16.80	4.92			
D196650	26.6	.08	.23	.41	1,250	1,275	1,305
	---	.13	.38	.67			
	---	.15	.43	.77			
D196651	22.9	.45	.67	.96	1,165	1,175	1,195
	---	.67	1.00	1.43			
	---	1.04	1.55	2.22			
D196652	19.6	.03	.10	.21	1,175	1,195	1,210
	---	.05	.15	.32			
	---	.06	.19	.39			
D196653	24.6	.05	.42	.42	1,190	1,205	1,225
	---	.08	.67	.67			
	---	.09	.78	.78			
D196654	24.4	.12	.25	.74	1,170	1,200	1,320
	---	.19	.39	1.15			
	---	.25	.53	1.56			

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D196655	36.9	26.2	27.3	9.6	6.7	37.5	0.6	44.3	1.4	3,440	6,190
	---	41.5	43.3	15.2	4.1	59.4	1.0	18.2	2.2	5,450	9,810
	---	49.0	51.0	---	4.9	70.1	1.1	21.5	2.6	6,430	11,570
D196657	38.2	25.8	28.3	7.7	6.9	37.9	.6	46.5	.4	3,490	6,280
	---	41.7	45.8	12.5	4.3	61.3	1.0	20.3	.6	5,650	10,160
	---	47.7	52.3	---	4.9	70.1	1.1	23.2	.7	6,450	11,610
D196658	37.5	22.5	22.7	17.3	6.2	31.9	.4	42.4	1.8	2,860	5,150
	---	36.0	36.3	27.7	3.3	51.0	.6	14.5	2.9	4,580	8,240
	---	49.8	50.2	---	4.5	70.6	.9	20.1	4.0	6,330	11,400
D196659	39.4	24.8	25.3	10.5	6.8	35.7	.5	45.6	.9	3,270	5,880
	---	40.9	41.7	17.3	4.0	58.9	.8	17.5	1.5	5,390	9,700
	---	49.5	50.5	---	4.8	71.3	1.0	21.1	1.8	6,520	11,740
D196661	32.6	25.4	23.3	18.7	5.8	30.5	.4	36.3	8.4	3,000	5,400
	---	37.7	34.6	27.7	3.2	45.3	.6	10.9	12.5	4,450	8,010
	---	52.2	47.8	---	4.5	62.6	.8	15.0	17.2	6,160	11,080
D196662	36.3	25.9	27.4	10.4	6.5	37.6	.6	43.3	1.5	3,550	6,380
	---	40.7	43.0	16.3	3.9	59.0	.9	17.3	2.4	5,570	10,020
	---	48.6	51.4	---	4.6	70.5	1.1	20.7	2.8	6,650	11,970
D196624	39.9	26.4	25.0	8.7	7.0	34.8	.4	48.6	.6	3,260	5,880
	---	43.9	41.6	14.5	4.3	57.9	.7	21.9	1.0	5,430	9,780
	---	51.4	48.6	---	5.0	67.7	.8	25.6	1.2	6,350	11,430
D196625	38.3	26.5	27.0	8.2	6.8	37.8	.6	45.9	.8	3,450	6,200
	---	42.9	43.8	13.3	4.1	61.3	1.0	19.2	1.3	5,590	10,050
	---	49.5	50.5	---	4.8	70.7	1.1	22.2	1.5	6,440	11,590
D196627	34.3	22.9	21.9	20.9	5.9	30.8	.5	38.9	3.2	2,780	5,000
	---	34.9	33.3	31.8	3.2	46.9	.8	12.8	4.9	4,230	7,610
	---	51.1	48.9	---	4.7	68.7	1.1	18.8	7.1	6,200	11,150
D196628	40.4	25.4	27.0	7.2	7.0	36.4	.6	48.4	.5	3,330	5,990
	---	42.6	45.3	12.1	4.2	61.1	1.0	21.0	.8	5,590	10,050
	---	48.5	51.5	---	4.8	69.5	1.1	23.8	1.0	6,350	11,440
D196629	39.2	28.3	25.8	6.7	7.3	37.7	.7	46.7	.9	3,610	6,490
	---	46.5	42.4	11.0	4.8	62.0	1.2	19.5	1.5	5,930	10,680
	---	52.3	47.7	---	5.4	69.7	1.3	21.9	1.7	6,670	12,000
D196630	26.2	38.8	26.6	8.4	7.0	39.3	.7	43.6	1.1	3,720	6,700
	---	52.6	36.0	11.4	5.5	53.3	.9	27.5	1.5	5,040	9,080
	---	59.3	40.7	---	6.3	60.1	1.1	31.1	1.7	5,690	10,240

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Air-dried loss	Forms of sulfur			Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic	Initial deformation	Softening	Fluid
D196655	25.6	0.27	0.72	0.44	1,150	1,165	1,180
	---	.43	1.14	.70			
	---	.50	1.35	.82			
D196657	25.3	.01	.09	.34	1,200	1,220	1,230
	---	.02	.15	.55			
	---	.02	.17	.63			
D196658	26.2	.29	1.02	.51	1,100	1,125	1,255
	---	.46	1.63	.82			
	---	.64	2.26	1.13			
D196659	27.2	.04	.72	.19	1,150	1,165	1,180
	---	.07	1.19	.31			
	---	.08	1.44	.38			
D196661	20.8	.54	7.55	.31	1,210	1,240	1,290
	---	.80	11.20	.46			
	---	1.11	15.50	.64			
D196662	21.6	.07	1.03	.41	1,060	1,080	1,100
	---	.11	1.62	.64			
	---	.13	1.93	.77			
D196624	27.2	.01L	.04	.52	1,165	1,195	1,240
	---	.01L	.07	.87			
	---	.01L	.08	1.01			
D196625	23.8	.03	.48	.25	1,245	1,265	1,290
	---	.05	.78	.41			
	---	.06	.90	.47			
D196627	22.3	.31	2.02	.82	1,130	1,160	1,190
	---	.47	3.07	1.25			
	---	.69	4.51	1.83			
D196628	26.9	.03	.29	.16	1,240	1,255	1,270
	---	.05	.49	.27			
	---	.06	.55	.31			
D196629	23.4	.01	.18	.71	1,240	1,255	1,270
	---	.02	.30	1.17			
	---	.02	.33	1.31			
D196630	23.4	.16	.15	.79	1,220	1,250	1,275
	---	.22	.20	1.07			
	---	.24	.23	1.21			

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D196631	35.4	30.0	27.1	7.5	6.9	40.1	0.7	44.4	0.4	3,780	6,800
	---	46.4	42.0	11.6	4.6	62.1	1.1	20.0	.6	5,850	10,520
	---	52.5	47.5	---	5.2	70.2	1.2	22.7	.7	6,610	11,900
D196632	39.7	24.9	27.4	8.0	6.8	37.4	.6	46.5	.8	3,430	6,170
	---	41.3	45.4	13.3	4.0	62.0	1.0	18.6	1.3	5,690	10,240
	---	47.6	52.4	---	4.6	71.5	1.1	21.4	1.5	6,560	11,800
D196634	37.0	24.3	25.8	12.9	6.5	32.8	.4	44.8	2.5	3,130	5,630
	---	38.6	41.0	20.5	3.8	52.1	.6	18.9	4.0	4,960	8,930
	---	48.5	51.5	---	4.8	65.5	.8	23.8	5.0	6,240	11,230
D196635	37.8	25.1	28.5	8.6	6.6	38.0	.6	45.6	.6	3,470	6,250
	---	40.4	45.8	13.8	3.9	61.1	1.0	19.3	1.0	5,580	10,050
	---	46.8	53.2	---	4.5	70.9	1.1	22.4	1.1	6,480	11,660
D196637	43.4	22.2	22.6	11.8	6.9	30.9	.5	49.1	.9	2,810	5,060
	---	39.2	39.9	20.8	3.7	54.6	.9	18.6	1.6	4,970	8,950
	---	49.6	50.4	---	4.6	69.0	1.1	23.5	2.0	6,280	11,300
D196638	40.6	24.7	26.6	8.1	6.9	36.1	.5	47.6	.7	3,280	5,900
	---	41.6	44.8	13.6	4.0	60.8	.8	19.4	1.2	5,520	9,930
	---	48.1	51.9	---	4.7	70.4	1.0	22.4	1.4	6,390	11,500
D196640	40.9	24.3	27.3	7.5	6.8	36.2	.5	48.0	.8	3,340	6,020
	---	41.1	46.2	12.7	3.8	61.3	.8	19.7	1.4	5,660	10,180
	---	47.1	52.9	---	4.4	70.2	1.0	22.6	1.6	6,480	11,660

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, and ash-fusion-temperature determinations for 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Air-dried loss	Forms of sulfur			Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic	Initial deformation	Softening	Fluid
D196631	22.6	0.01	0.01	0.38	1,165	1,180	1,210
	---	.02	.02	.59			
	---	.02	.02	.67			
D196632	26.2	.02	.34	.39	1,115	1,140	1,160
	---	.03	.56	.65			
	---	.04	.65	.75			
D196634	24.3	.52	.90	1.12	1,105	1,130	1,190
	---	.83	1.43	1.78			
	---	1.04	1.80	2.24			
D196635	21.8	.01	.27	.34	1,165	1,180	1,200
	---	.02	.43	.55			
	---	.02	.50	.63			
D196637	32.6	.11	.45	.31	1,165	1,180	1,200
	---	.19	.80	.55			
	---	.25	1.00	.69			
D196638	30.1	.04	.40	.28	1,255	1,270	1,290
	---	.07	.67	.47			
	---	.08	.78	.55			
D196640	29.9	.04	.43	.35	1,220	1,230	1,250
	---	.07	.73	.59			
	---	.08	.83	.68			

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.

[Lignite ashed at 525° C. L, less than the value shown; G, greater than the value shown; N not detected; B, not determined. S after element title indicates determinations by semiquantitative emission spectrography. The spectrographic results are to be identified with geometric brackets whose boundaries are part of the ascending series 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, 1.2, etc. but reported as midpoints of the brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, etc. Precision of the spectrographic data is plus-or-minus one bracket at 68 percent or plus-or-minus two brackets at 95 percent confidence level]

Sample number	Ash (percent)	SiO2 (percent)	Al2O3 (percent)	CaO (percent)	MgO (percent)	Na2O (percent)	K2O (percent)	Fe2O3 (percent)	TiO2 (percent)	P2O5 (percent)	Sample number
D188118	13.7	35	14	25	7.55	2.00	0.84	3.3	0.57	1.0L	D188118
D188119	9.4	16	6.1	35	7.63	3.33	.60	6.4	.55	1.0L	D188119
D188120	10.2	24	11	32	7.85	3.45	.61	3.8	.53	1.0L	D188120
D188121	9.2	12	7.3	28	7.10	8.75	.33	9.7	.27	1.0L	D188121
D188122	8.8	22	10	29	7.10	9.28	.39	2.1	.44	1.0L	D188122
D188123	13.1	26	14	24	5.05	4.30	.45	7.5	.61	1.0L	D188123
D188124	10.3	13	4.2	24	5.98	6.83	.37	15	.43	1.0L	D188124
D188125	7.7	7.6	5.0	40	11.8	2.48	.40	5.3	.58	1.0L	D188125
D188126	6.7	13	6.9	36	9.38	3.28	.39	7.5	.61	1.0L	D188126
D188136	14.7	22	9.7	21	5.80	.30	.84	15	.48	1.0L	D188136
D188137	8.4	17	7.3	37	10.6	.35	.28	.65	.49	1.0L	D188137
D188138	11.1	21	9.7	22	5.25	8.43	1.0	6.6	.86	1.0L	D188138
D188140	10.4	33	11	13	3.65	8.60	1.5	6.4	.66	1.0L	D188140
D188141	12.4	14	7.6	18	4.70	8.05	.33	16	.95	1.0L	D188141
D188142	9.4	25	10	22	6.13	10.6	.50	4.3	1.1	1.0L	D188142
D188143	9.1	22	13	24	6.20	11.1	.55	4.8	1.0	1.0L	D188143
D188128	14.5	18	10	22	6.45	.23	.36	16	.69	1.0L	D188128
D188129	10.4	21	9.1	28	8.85	.30	.46	7.5	.77	1.0L	D188129
D188130	12.9	29	12	22	7.05	.33	.73	7.2	.66	1.0L	D188130
D188131	8.4	14	8.6	36	12.4	.34	.35	3.0	.52	1.0L	D188131
D188132	10.3	14	8.0	29	10.3	.32	.39	8.4	.80	1.0L	D188132
D188133	16.8	49	14	14	4.78	.24	2.5	2.0	.75	1.0L	D188133
D188134	19.0	45	16	16	5.43	.35	1.5	2.7	.83	1.0L	D188134
D188135	10.1	9.8	6.9	26	7.10	.18	.33	20	.40	1.0L	D188135
D188144	9.7	31	8.0	24	7.43	2.95	.64	7.5	.77	1.0L	D188144
D188145	14.0	22	12	19	3.65	6.78	.37	13	1.1	1.0L	D188145
D196641	12.9	28	11	14	5.90	.37	1.0	7.3	.60	.07	D196641
D196642	17.5	11	7.0	8.6	4.10	.21	.50	36	.20	.08L	D196642
D196643	13.2	32	11	14	6.40	1.07	1.1	8.3	.60	.61	D196643
D196645	13.6	29	13	14	5.70	2.86	.50	4.5	1.1	.22	D196645
D196647	17.2	18	6.0	9.1	3.70	2.25	.70	24	.80	.06L	D196647
D196648	14.0	28	11	12	4.60	2.80	1.2	5.9	.40	.07L	D196648
D196649	40.2	16	4.3	2.3	.95	.62	.70	53	.10	.02L	D196649
D196650	10.9	24	13	19	7.00	3.02	.50	4.0	.70	.18	D196650
D196651	31.9	55	17	3.7	2.08	1.09	1.9	6.0	.50	.03L	D196651
D196652	17.0	47	13	11	4.90	1.89	.80	2.8	.90	.12	D196652
D196653	10.5	25	13	16	6.10	1.77	.60	8.3	.40	.19	D196653
D196654	27.1	56	13	5.1	3.10	1.70	3.0	5.5	.50	.04L	D196654
D196655	15.2	21	7.8	11	4.10	2.31	.60	19	.60	.13	D196655
D196657	10.6	25	17	15	5.90	6.80	.40	3.7	.50	.09L	D196657

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	SO3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Sample number
D188118	5.2	N	700	700	N	1.0L	35	30	N	N	D188118
D188119	12	N	1,500	3,000	N	1.0L	33	15	N	N	D188119
D188120	9.6	N	1,500	300	N	1.0L	54	30	N	N	D188120
D188121	22	N	1,500	700	N	3.0	37	15	N	N	D188121
D188122	6.4	N	1,500	500	5	1.0L	44	15	N	N	D188122
D188123	17	N	700	2,000	N	1.0L	37	30	N	N	D188123
D188124	30	N	700	700	N	1.0L	44	15	N	N	D188124
D188125	5.8	N	700	7,000	N	1.0L	29	10	N	N	D188125
D188126	11	N	1,500	3,000	5	1.0L	60	20	N	N	D188126
D188136	26	N	500	1,500	3	1.0L	35	15	N	N	D188136
D188137	13	N	1,000	300	N	1.0L	46	15	N	N	D188137
D188138	22	N	1,000	10,000	10	1.0L	79	30	N	N	D188138
D188140	23	N	700	7,000	15	1.0L	73	70	30	N	D188140
D188141	29	N	700	7,000	N	1.0L	33	20	N	N	D188141
D188142	13	N	700	10,000	15	1.0L	52	30	N	70	D188142
D188143	10	N	700	15,000	7	1.0L	62	50	20	70	D188143
D188128	27	3	700	7,000	5	1.0L	37	15	N	N	D188128
D188129	18	N	700	3,000	3	1.0L	66	30	N	70	D188129
D188130	13	N	700	500	7	1.0L	68	15	N	N	D188130
D188131	13	N	700	1,500	N	1.0L	46	15	N	N	D188131
D188132	20	N	700	7,000	N	1.0L	39	15	N	N	D188132
D188133	4.9	N	300	1,500	N	1.0L	50	30	N	N	D188133
D188134	7.9	N	300	1,500	3	1.0L	93	30	N	N	D188134
D188135	32	N	700	700	N	1.0L	33	15	N	N	D188135
D188144	17	N	1,500	2,000	10	1.0L	64	30	N	N	D188144
D188145	24	N	700	7,000	7	1.0L	37	30	N	N	D188145
D196641	7.9	N	1,000	3,000	15	1.0L	132	70	50	N	D196641
D196642	8.7	N	700	150	20	1.0L	48	70	70	N	D196642
D196643	7.9	N	1,000	1,000	3	1.0L	72	15	N	N	D196643
D196645	7.7	N	1,000	20,000	3	1.0L	39	30	N	N	D196645
D196647	11	N	700	20,000	3	1.0L	35	20	N	N	D196647
D196648	12	N	1,500	500	7	1.0L	62	30	N	N	D196648
D196649	5.5	N	200	1,000	10	1.0L	44	B	N	N	D196649
D196650	9.0	N	1,500	3,000	3	1.0L	44	20	N	N	D196650
D196651	3.7	N	500	700	7	1.0L	93	30	N	N	D196651
D196652	3.5	N	1,000	3,000	3	1.0L	44	30	N	N	D196652
D196653	9.9	N	1,500	1,000	5	1.0L	49	30	N	N	D196653
D196654	4.8	N	500	1,000	10	1.0L	90	70	N	N	D196654
D196655	12	N	700	5,000	3	1.0L	42	15	N	N	D196655
D196657	6.8	N	1,500	500	10	1.0L	65	50	N	N	D196657

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Sample number
D188118	84	405	15	N	7	50	10	3,000	30	50	D188118
D188119	16	1,530	30	N	10	25	N	5,000	30	20	D188119
D188120	37	695	15	30	20	50	10	5,000	70	50	D188120
D188121	28	785	15	N	7	40	7	7,000	30	30	D188121
D188122	39	840	15	N	15	25	15	7,000	70	70	D188122
D188123	127	625	15	30	7	40	7	3,000	30	30	D188123
D188124	19	725	10	N	7	30	N	7,000	30	20	D188124
D188125	10L	860	7	N	10	35	N	7,000	30	20	D188125
D188126	20	960	30	N	15	40	7	5,000	70	70	D188126
D188136	46	490	30	20	7	50	7	1,500	30	30	D188136
D188137	28	970	15	N	7	25	N	3,000	30	20	D188137
D188138	37	630	30	20	15	45	15	3,000	150	70	D188138
D188140	27	300	70	50	30	30	30	2,000	300	150	D188140
D188141	31	430	15	N	7	25	7	5,000	50	30	D188141
D188142	39	360	30	30	15	45	15	5,000	70	70	D188142
D188143	55	350	20	20	15	45	20	7,000	150	70	D188143
D188128	40	525	20	N	7	35	N	1,500	30	50	D188128
D188129	28	635	15	30	20	40	7	3,000	70	70	D188129
D188130	45	550	15	20	30	35	15	1,500	70	70	D188130
D188131	40	1,110	N	N	7	50	N	3,000	30	20	D188131
D188132	49	1,150	15	20	5	40	N	3,000	30	20	D188132
D188133	43	505	N	20	7	30	15	1,500	70	30	D188133
D188134	84	610	15	20	15	40	15	2,000	70	30	D188134
D188135	25	525	20	N	15	35	N	700	30	30	D188135
D188144	34	855	30	20	15	30	30	2,000	70	70	D188144
D188145	77	530	20	20	15	45	10	3,000	30	50	D188145
D196641	42	530	20	30	30	30	30	500	300	100	D196641
D196642	31	330	70	50	200	30	30	1,000	200	100	D196642
D196643	41	640	10	N	15	30	10L	1,500	50	20	D196643
D196645	52	1,000	10	N	10	40	15	2,000	70	50	D196645
D196647	17	490	30	N	20	25L	10	2,000	50	30	D196647
D196648	35	520	30	20L	20	25L	20	1,500	150	70	D196648
D196649	14	245	50	N	70	25L	15	500	70	30	D196649
D196650	138	1,170	15	N	15	45	10	2,000	30	30	D196650
D196651	101	285	30	20	50	30	30	700	150	70	D196651
D196652	69	660	10	20	15	40	10	2,000	70	30	D196652
D196653	99	950	15	20L	15	40	15	2,000	70	50	D196653
D196654	43	360	50	20L	50	25L	30	1,000	100	70	D196654
D196655	35	800	20	N	20	25L	10	2,000	30	30	D196655
D196657	78	1,040	30	N	15	30	20	1,500	70	70	D196657

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D188118	3	34	150
D188119	2	35	30
D188120	3	78	100
D188121	3	48	150
D188122	7	28	150
D188123	3	24	150
D188124	3	30	30
D188125	3	34	30
D188126	5	39	70
D188136	5	59	70
D188137	3	33	70
D188138	7	96	150
D188140	15	118	150
D188141	3	45	150
D188142	7	50	150
D188143	7	28	200
D188128	5	38	100
D188129	5	72	100
D188130	7	84	150
D188131	2	34	70
D188132	2	40	70
D188133	3	47	100
D188134	5	62	150
D188135	3	38	70
D188144	7	36	150
D188145	5	35	150
D196641	15	1,200	300
D196642	15	323	500
D196643	3	304	100
D196645	3	65	150
D196647	B	67	100
D196648	7	121	150
D196649	B	186	150
D196650	3	57	150
D196651	7	233	150
D196652	3	88	150
D196653	5	160	150
D196654	10	240	150
D196655	B	103	100
D196657	5	241	200

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Ash (percent)	SiO2 (percent)	Al2O3 (percent)	CaO (percent)	MgO (percent)	Na2O (percent)	K2O (percent)	Fe2O3 (percent)	TiO2 (percent)	P2O5 (percent)	Sample number
D196658	22.9	44	9.0	7.4	4.60	0.18	1.1	10	1.2	0.04L	D196658
D196659	13.4	24	8.0	17	6.60	.26	.80	8.5	.50	.15	D196659
D196661	26.4	12	5.4	5.4	2.43	.60	.20	46	.20	.04L	D196661
D196662	13.0	28	12	12	4.70	5.50	.70	11	.50	.08L	D196662
D196624	14.4	50	14	7.5	4.90	.76	2.3	3.2	.60	.07L	D196624
D196625	10.5	25	8.2	25	8.20	.78	.50	3.4	.60	.57	D196625
D196627	28.8	55	6.9	7.0	2.86	.19	.80	3.9	3.1	.03L	D196627
D196628	12.0	24	9.6	19	7.00	.33	.70	7.8	.60	.16	D196628
D196629	10.4	20	12	18	6.60	1.41	.40	7.6	.50	.10	D196629
D196630	12.5	8.0	5.5	12	4.70	1.51	.50	7.3	6.4	.08L	D196630
D196631	12.0	39	12	15	5.40	5.50	.70	3.3	.70	.08L	D196631
D196632	10.5	23	9.7	16	6.40	7.30	.40	6.2	.60	.19	D196632
D196634	21.3	36	12	4.8	2.66	3.14	1.8	16	.60	.05	D196634
D196635	11.3	31	13	15	5.90	6.50	.60	3.6	.70	.09L	D196635
D196637	17.6	31	11	13	5.50	.83	.40	7.3	.80	.06L	D196637
D196638	10.4	20	11	22	7.90	1.13	.50	7.5	.50	.48	D196638
D196640	12.1	21	11	18	6.50	.76	.50	6.8	.50	.74	D196640

Sample number	SO3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Sample number
D196658	7.6	N	700	5,000	7	1.0L	58	30	N	N	D196658
D196659	11	N	1,000	1,000	7	1.0L	53	20	N	N	D196659
D196661	6.7	N	300	2,000	10	1.0L	16	20	30	N	D196661
D196662	11	N	1,000	500	10	1.0L	58	30	N	N	D196662
D196624	4.4	N	1,000	1,000	15	1.0L	72	70	20L	N	D196624
D196625	5.1	N	1,500	1,000	5	1.0L	53	20	N	N	D196625
D196627	5.4	N	700	20,000	15	1.0L	35	50	20L	N	D196627
D196628	7.6	N	1,500	2,000	5	1.0L	37	30	N	N	D196628
D196629	9.4	N	1,500	1,000	15	4.0	203	50	20L	N	D196629
D196630	13	N	1,500	20,000G	20	1.0L	72	100	70	N	D196630
D196631	4.4	N	1,500	1,000	30	1.0L	67	50	50	N	D196631
D196632	9.4	N	1,500	2,000	3	2.0	39	20	N	N	D196632
D196634	7.0	N	700	700	7	1.0L	116	70	30	N	D196634
D196635	6.5	N	1,000	3,000	3	1.0L	39	30	N	N	D196635
D196637	7.4	N	700	1,000	3	1.0L	72	30	20L	N	D196637
D196638	9.8	N	1,500	2,000	3	1.0L	35	15	N	N	D196638
D196640	8.8	N	1,500	3,000	3	1.0L	35	15	20L	N	D196640

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Sample number
D196658	41	185	15	20	20	25L	15	1,000	70	70	D196658
D196659	32	680	15	20	15	35	15	1,500	70	70	D196659
D196661	33	150	30	N	15	30	15	1,000	30	30	D196661
D196662	53	490	30	20L	15	45	15	2,000	70	50	D196662
D196624	41	285	20	20L	15	40	50	1,500	150	100	D196624
D196625	33	1,800	20	20L	10	35	15	2,000	70	70	D196625
D196627	41	180	10	20L	15	25	30	1,500	100	100	D196627
D196628	39	800	30	20L	10	35	15	2,000	70	30	D196628
D196629	52	740	70	20L	30	30	20	1,500	150	70	D196629
D196630	10L	255	50	70	50	25	30	2,000	300	100	D196630
D196631	57	740	15	30	20	50	30	1,500	150	150	D196631
D196632	41	960	15	20	10	40	10	2,000	50	30	D196632
D196634	32	290	70	50	200	45	30	1,000	300	100	D196634
D196635	52	1,240	10	20L	15	40	10L	2,000	50	30	D196635
D196637	70	590	7	20L	10	35	15	1,500	70	50	D196637
D196638	45	1,220	15	N	15	45	10L	2,000	15	30	D196638
D196640	47	1,480	15	20L	15	25L	10L	2,000	30	30	D196640

Sample number	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D196658	7	171	200
D196659	7	40	150
D196661	B	500	150
D196662	5	42	150
D196624	10	112	200
D196625	5	57	150
D196627	7	87	300
D196628	3	54	150
D196629	7	800	150
D196630	15	275	500
D196631	15	256	500
D196632	3	184	150
D196634	15	800	300
D196635	3	261	150
D196637	3	106	150
D196638	2	48	100
D196640	3	140	150

Table 4.--Content of nine trace elements in 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Gold Valley County, N. Dak.

[Analyses in air-dried (32° C) lignite. L, less than the value shown]

Sample number	As (ppm)	Co (ppm)	Cr (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D188118	1.9	0.6	3.2	40	0.08	0.3	0.9	2.7	1.5	D188118
D188119	2.7	.5	1.9	25	.16	.2	.3	.5	2.1	D188119
D188120	2.5	2.0	4.2	30	.03	.4	.4	1.8	1.7	D188120
D188121	.7	.4	1.3	25	.05	.2	.5	.9	1.0	D188121
D188122	.9	1.0	2.0	40	.03	.3	.4	1.1	1.2	D188122
D188123	1.5	.5	3.1	45	.08	.3	1.2	2.5	2.1	D188123
D188124	1.7	.9	1.7	30	.08	.2	.6	.9	1.1	D188124
D188125	1.2	.4	1.0	30	.02	.1	.3	.4	.2L	D188125
D188126	2.7	1.1	2.2	30	.03	.3	.4	.9	1.2	D188126
D188136	6.0	1.2	3.4	45	.10	.8	.8	2.1	3.1	D188136
D188137	.9	.5	1.2	45	.02	.1	.4	.7	.8	D188137
D188138	6.3	1.1	3.5	45	.05	1.1	.6	1.3	2.9	D188138
D188140	15	2.1	5.1	55	.05	2.5	.4	1.7	6.5	D188140
D188141	4.8	.7	2.0	30	.03	.6	.6	1.5	1.4	D188141
D188142	1.0L	1.5	3.0	45	.03	.6	.1L	1.7	1.2	D188142
D188143	3.1	.8	2.4	60	.03	.9	.5	1.8	1.9	D188143
D188128	4.2	.7	2.5	20L	.20	.5	.5	2.4	2.5	D188128
D188129	6.4	2.5	2.7	25	.08	1.0	.8	1.7	1.7	D188129
D188130	110	2.7	4.5	40	.24	1.0	1.1	2.5	1.8	D188130
D188131	1.3	.4	1.5	20L	.03	.2	.7	1.0	.7	D188131
D188132	2.1	.4	1.8	25	.09	.2	.7	1.2	.9	D188132
D188133	2.5	1.2	12	150	.06	.6	.7	3.1	1.6	D188133
D188134	45	1.3	7.9	100	.24	1.0	.9	3.7	2.2	D188134
D188135	1.9	2.0	1.4	30	.07	.1	.7	.9	13	D188135
D188144	1.3	1.5	3.2	20	.04	.4	.6	1.5	1.8	D188144
D188145	5.6	1.1	3.0	25	.10	.6	.8	2.1	1.6	D188145
D196641	13	4.9	14	45	.08	2.1	.8	2.8	13	D196641
D196642	180	43	9.1	25	.79	11	1.7	3.5	17	D196642
D196643	8.3	1.3	6.0	50	.14	.7	1.0	2.4	1.5	D196643
D196645	5.6	.6	3.6	30	.09	.3	.7	2.1	1.5	D196645
D196647	28	1.0	4.3	25	.21	.9	.4	1.8	2.2	D196647
D196648	33	1.3	7.3	45	.11	1.4	.4	1.6	2.9	D196648
D196649	170	8.4	15	50	.74	4.0	.8	.1L	5.4	D196649
D196650	2.6	.9	2.4	25	.08	.3	.1L	1.8	.9	D196650
D196651	19	7.7	22	180	.46	2.9	.8	5.7	7.4	D196651
D196652	3.5	1.0	6.3	45	.10	.4	.8	3.8	1.5	D196652
D196653	3.5	1.0	3.3	30	.15	.5	.5	1.6	1.2	D196653
D196654	23	6.7	20	190	.18	3.8	.1L	4.3	16	D196654
D196655	19	1.7	4.3	25	.18	1.8	.1L	2.3	1.8	D196655
D196657	18	1.2	.1L	25	.13	.8	.7	2.4	1.4	D196657

Table 4.--Content of nine trace elements in 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Gold Valley County, N. Dak.--continued

Sample number	As (ppm)	Co (ppm)	Cr (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D196658	19	2.6	8.6	55	0.12	3.6	1.3	3.7	5.2	D196658
D196659	10	.9	6.2	25	.14	.4	.7	2.7	2.1	D196659
D196661	22	2.3	4.5	20L	.56	1.5	.9	2.5	1.8	D196661
D196662	8.4	1.5	4.0	30	.19	1.0	.5	2.1	1.8	D196662
D196624	8.9	1.6	9.8	90	.06	1.9	.6	2.5	11	D196624
D196625	2.2	1.1	3.6	20	.06	.4	.7	2.4	.8	D196625
D196627	10	2.0	14	40	.18	2.0	1.2	5.3	9.8	D196627
D196628	4.6	.8	3.7	20	.06	.4	.6	2.0	2.7	D196628
D196629	15	3.0	4.0	20	.23	1.1	.5	1.6	2.4	D196629
D196630	19	6.2	6.3	20	.10	4.7	.6	1.1	10	D196630
D196631	5.2	3.1	5.1	25	.06	1.1	1.0	3.6	4.1	D196631
D196632	4.5	.5	3.0	25	.15	.4	.7	1.8	.9	D196632
D196634	63	28	29	110	1.23	7.3	1.1	5.7	13	D196634
D196635	6.3	.7	3.3	35	.11	.4	.7	2.3	.8	D196635
D196637	7.1	.6	6.3	20	.24	.8	1.6	4.4	4.3	D196637
D196638	6.6	.6	1.7	20	.15	.6	.1L	1.4	.9	D196638
D196640	1.6	3.5	2.8	25	.08	.3	.6	1.8	1.2	D196640

Table 5.--Major-, minor-, and trace-element compositon of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.

[Values in percent or parts per million. As, Co, Cr, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32° C) lignite; all other values calculated from analyses of lignite ash. S means analysis by emission spectrography; L, less than the value shown; G, greater than the value shown; N, not detected; B, not determined]

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)	Sample number
D188118	2.2	1.0	2.4	0.62	0.20	0.096	0.32	0.047	N	1.9	D188118
D188119	.70	.30	2.3	.43	.23	.047	.42	.031	N	2.7	D188119
D188120	1.1	.59	2.3	.48	.26	.052	.27	.032	N	2.5	D188120
D188121	.52	.36	1.8	.39	.60	.025	.62	.015	N	.7	D188121
D188122	.90	.47	1.8	.38	.61	.029	.13	.023	N	.9	D188122
D188123	1.6	.97	2.2	.40	.42	.049	.69	.048	N	1.5	D188123
D188124	.63	.23	1.8	.37	.52	.032	1.1	.027	N	1.7	D188124
D188125	.27	.20	2.2	.55	.14	.026	.29	.027	N	1.2	D188125
D188126	.41	.24	1.7	.38	.16	.022	.35	.024	N	2.7	D188126
D188136	1.5	.75	2.2	.51	.033	.10	1.5	.042	N	6.0	D188136
D188137	.67	.32	2.2	.54	.022	.020	.038	.025	N	.9	D188137
D188138	1.1	.57	1.7	.35	.69	.092	.51	.057	N	6.3	D188138
D188140	1.6	.61	.97	.23	.66	.13	.47	.041	N	15	D188140
D188141	.81	.50	1.6	.35	.74	.034	1.4	.071	N	4.8	D188141
D188142	1.1	.50	1.5	.35	.74	.039	.28	.062	N	1.0L	D188142
D188143	.93	.63	1.6	.34	.75	.042	.31	.055	N	3.1	D188143
D188128	1.2	.77	2.3	.56	.025	.043	1.6	.060	.5	4.2	D188128
D188129	1.0	.50	2.1	.55	.023	.040	.55	.048	N	6.4	D188129
D188130	1.7	.82	2.0	.55	.032	.078	.65	.051	N	110	D188130
D188131	.55	.38	2.2	.63	.021	.024	.18	.026	N	1.3	D188131
D188132	.67	.44	2.1	.64	.024	.033	.60	.049	N	2.1	D188132
D188133	3.8	1.2	1.7	.48	.030	.35	.23	.075	N	2.5	D188133
D188134	4.0	1.6	2.2	.62	.049	.24	.36	.094	N	45	D188134
D188135	.46	.37	1.9	.43	.013	.028	1.4	.024	N	1.9	D188135
D188144	1.4	.41	1.7	.43	.21	.052	.51	.045	N	1.3	D188144
D188145	1.4	.89	1.9	.31	.70	.043	1.3	.092	N	5.6	D188145
D196641	1.7	.75	1.3	.46	.035	.11	.66	.046	N	13	D196641
D196642	.90	.65	1.1	.43	.027	.073	4.4	.021	N	180	D196642
D196643	2.0	.77	1.3	.51	.10	.12	.77	.047	N	8.3	D196643
D196645	1.8	.94	1.4	.47	.29	.057	.43	.090	N	5.6	D196645
D196647	1.4	.55	1.1	.38	.29	.10	2.9	.082	N	28	D196647
D196648	1.8	.81	1.2	.39	.29	.14	.58	.034	N	33	D196648
D196649	3.0	.91	.66	.23	.18	.23	15	.024	N	170	D196649
D196650	1.2	.75	1.5	.46	.24	.045	.30	.046	N	2.6	D196650
D196651	8.2	2.9	.84	.40	.26	.50	1.3	.096	N	19	D196651
D196652	3.7	1.2	1.3	.50	.24	.11	.33	.092	N	3.5	D196652
D196653	1.2	.72	1.2	.39	.14	.052	.61	.025	N	3.5	D196653
D196654	7.1	1.9	.99	.51	.34	.68	1.0	.081	N	23	D196654
D196655	1.5	.63	1.2	.38	.26	.076	2.0	.055	N	19	D196655
D196657	1.2	.95	1.1	.38	.53	.035	.27	.032	N	18	D196657

Table 5.--Major-, minor-, and trace-element compositon of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)	Sample number
D188118	100	100	N	0.14L	0.6	3.2	4.8	40	5	N	D188118
D188119	150	300	N	.09L	.5	1.9	3.1	25	1.5	N	D188119
D188120	150	30	N	.10L	2.0	4.2	5.5	30	3	N	D188120
D188121	150	70	N	.28	.4	1.3	3.4	25	1.5	N	D188121
D188122	150	50	.5	.09L	1.0	2.0	3.9	40	1.5	N	D188122
D188123	100	300	N	.13L	.5	3.1	4.8	45	5	N	D188123
D188124	70	70	N	.10L	.9	1.7	4.5	30	1.5	N	D188124
D188125	50	500	N	.08L	.4	1.0	2.2	30	.7	N	D188125
D188126	100	200	.3	.07L	1.1	2.2	4.0	30	1.5	N	D188126
D188136	70	200	.5	.15L	1.2	3.4	5.1	45	2	N	D188136
D188137	100	20	N	.08L	.5	1.2	3.9	45	1.5	N	D188137
D188138	100	1,000	1	.11L	1.1	3.5	8.8	45	3	N	D188138
D188140	70	700	1.5	.10L	2.1	5.1	7.6	55	7	3	D188140
D188141	100	1,000	N	.12L	.7	2.0	4.1	30	2	N	D188141
D188142	70	1,000	1.5	.09L	1.5	3.0	4.9	45	3	N	D188142
D188143	70	1,500	.7	.09L	.8	2.4	5.6	60	5	2	D188143
D188128	100	1,000	.7	.15L	.7	2.5	5.4	20L	2	N	D188128
D188129	70	300	.3	.10L	2.5	2.7	6.9	25	3	N	D188129
D188130	100	70	1	.13L	2.7	4.5	8.8	40	2	N	D188130
D188131	70	150	N	.08L	.4	1.5	3.9	20L	1.5	N	D188131
D188132	70	700	N	.10L	.4	1.8	4.0	25	1.5	N	D188132
D188133	50	200	N	.17L	1.2	12	8.4	150	5	N	D188133
D188134	70	300	.7	.19L	1.3	7.9	18	100	7	N	D188134
D188135	70	70	N	.10L	2.0	1.4	3.3	30	1.5	N	D188135
D188144	150	200	1	.10L	1.5	3.2	6.2	20	3	N	D188144
D188145	100	1,000	1	.14L	1.1	3.0	5.2	25	5	N	D188145
D196641	150	500	2	.13L	4.9	14	17	45	10	7	D196641
D196642	150	30	3	.18L	43	9.1	8.4	25	15	15	D196642
D196643	150	150	.5	.13L	1.3	6.0	9.5	50	2	N	D196643
D196645	150	3,000	.5	.14L	.6	3.6	5.3	30	5	N	D196645
D196647	100	3,000	.5	.17L	1.0	4.3	6.0	25	3	N	D196647
D196648	200	70	1	.14L	1.3	7.3	8.7	45	5	N	D196648
D196649	70	500	5	.40L	8.4	15	18	50	B	N	D196649
D196650	150	300	.3	.11L	.9	2.4	4.8	25	2	N	D196650
D196651	150	200	2	.32L	7.7	22	30	180	10	N	D196651
D196652	150	500	.5	.17L	1.0	6.3	7.5	45	5	N	D196652
D196653	150	100	.5	.11L	1.0	3.3	5.1	30	3	N	D196653
D196654	150	300	3	.27L	6.7	20	24	190	20	N	D196654
D196655	100	700	.5	.15L	1.7	4.3	6.4	25	2	N	D196655
D196657	150	50	1	.11L	1.2	.1L	6.9	25	5	N	D196657

Table 5.--Major-, minor-, and trace-element compositon of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sample number
D188118	0.08	N	12	55	2	N	1	600L	6.9	0.3	D188118
D188119	.16	N	1.5	140	3	N	1	410L	2.4	.2	D188119
D188120	.03	N	3.8	71	1.5	3	2	450L	5.1	.4	D188120
D188121	.05	N	2.6	72	1.5	N	.7	400L	3.7	.2	D188121
D188122	.03	N	3.4	74	1.5	N	1.5	380L	2.2	.3	D188122
D188123	.08	N	17	82	2	5	1	570L	5.2	.3	D188123
D188124	.08	N	2.0	75	1	N	.7	450L	3.1	.2	D188124
D188125	.02	N	.8L	66	.5	N	.7	340L	2.7	.1	D188125
D188126	.03	N	1.3	64	2	N	1	290L	2.7	.3	D188126
D188136	.10	N	6.8	72	5	3	1	640L	7.4	.8	D188136
D188137	.02	N	2.4	81	1.5	N	.7	370L	2.1	.1	D188137
D188138	.05	N	4.1	70	3	2	1.5	490L	5.0	1.1	D188138
D188140	.05	N	2.8	31	7	5	3	450L	3.1	2.5	D188140
D188141	.03	N	3.8	53	2	N	1	540L	3.1	.6	D188141
D188142	.03	7	3.7	34	3	3	1.5	410L	4.2	.6	D188142
D188143	.03	7	5.0	32	2	2	1.5	400L	4.1	.9	D188143
D188128	.20	N	5.8	76	3	N	1	630L	5.1	.5	D188128
D188129	.08	7	2.9	66	1.5	3	2	450L	4.2	1.0	D188129
D188130	.24	N	5.8	71	2	2	5	560L	4.5	1.0	D188130
D188131	.03	N	3.4	93	N	N	.7	370L	4.2	.2	D188131
D188132	.09	N	5.0	120	1.5	2	.5	450L	4.1	.2	D188132
D188133	.06	N	7.2	85	N	3	1	730L	5.0	.6	D188133
D188134	.24	N	16	120	3	3	3	830L	7.6	1.0	D188134
D188135	.07	N	2.5	53	2	N	1.5	440L	3.5	.1	D188135
D188144	.04	N	3.3	83	3	2	1.5	420L	2.9	.4	D188144
D188145	.10	N	11	74	3	3	2	610L	6.3	.6	D188145
D196641	.08	N	5.4	68	2	5	39	3.9	2.1	D196641
D196642	.79	N	5.4	58	15	10	30	61L	5.3	11.0	D196642
D196643	.14	N	5.4	84	1.5	N	2	350	4.0	.7	D196643
D196645	.09	N	7.1	140	1.5	N	1.5	130	5.4	.3	D196645
D196647	.21	N	2.9	84	5	N	3	45L	4.3L	.9	D196647
D196648	.11	N	4.9	73	5	3L	3	43L	3.5L	1.4	D196648
D196649	.74	N	5.6	98	20	N	30	35L	10L	4.0	D196649
D196650	.08	N	15	130	1.5	N	1.5	86	4.9	.3	D196650
D196651	.46	N	32	91	10	7	15	42L	9.6	2.9	D196651
D196652	.10	N	12	110	1.5	3	2	89	6.8	.4	D196652
D196653	.15	N	10	100	1.5	2L	1.5	87	4.2	.5	D196653
D196654	.18	N	12	98	15	5L	15	47L	6.8L	3.8	D196654
D196655	.18	N	5.3	120	3	N	3	86	3.8L	1.8	D196655
D196657	.13	N	8.3	110	3	N	1.5	42L	3.2	.8	D196657

Table 5.--Major-, minor-, and trace-element compositon of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D188118	1.5	0.9	500	2.7	1.5	5	7	0.5	4.7	20	D188118
D188119	N	.3	500	.5	2.1	3	2	.2	3.3	3	D188119
D188120	1	.4	500	1.8	1.7	7	5	.3	8.0	10	D188120
D188121	.7	.5	700	.9	1.0	3	3	.3	4.4	15	D188121
D188122	1.5	.4	700	1.1	1.2	7	7	.7	2.5	15	D188122
D188123	1	1.2	500	2.5	2.1	5	5	.5	3.1	20	D188123
D188124	N	.6	700	.9	1.1	3	2	.3	3.1	3	D188124
D188125	N	.3	500	.4	.2L	2	1.5	.2	2.6	2	D188125
D188126	.5	.4	300	.9	1.2	5	5	.3	2.6	5	D188126
D188136	1	.8	200	2.1	3.1	5	5	.7	8.7	10	D188136
D188137	N	.4	200	.7	.8	2	1.5	.2	2.8	7	D188137
D188138	1.5	.6	300	1.3	2.9	15	7	.7	11	15	D188138
D188140	3	.4	200	1.7	6.5	30	15	1.5	12	15	D188140
D188141	1	.6	700	1.5	1.4	7	3	.3	5.6	20	D188141
D188142	1.5	.1L	500	1.7	1.2	7	7	.7	4.7	15	D188142
D188143	2	.5	700	1.8	1.9	15	7	.7	2.5	20	D188143
D188128	N	.5	200	2.4	2.5	5	7	.7	5.5	15	D188128
D188129	.7	.8	300	1.7	1.7	7	7	.5	7.5	10	D188129
D188130	2	1.1	200	2.5	1.8	10	10	1	11	20	D188130
D188131	N	.7	200	1.0	.7	2	1.5	.15	2.9	7	D188131
D188132	N	.7	300	1.2	.9	3	2	.2	4.1	7	D188132
D188133	2	.7	200	3.1	1.6	10	5	.5	7.9	15	D188133
D188134	3	.9	300	3.7	2.2	15	7	1	12	30	D188134
D188135	N	.7	70	.9	13	3	3	.3	3.8	7	D188135
D188144	3	.6	200	1.5	1.8	7	7	.7	3.5	15	D188144
D188145	1.5	.8	500	2.1	1.6	5	7	.7	4.9	20	D188145
D196641	5	.8	70	2.8	13	50	15	2	150	50	D196641
D196642	5	1.7	150	3.5	17	30	15	3	57	100	D196642
D196643	1.5L	1.0	200	2.4	1.5	7	3	.5	40	15	D196643
D196645	2	.7	300	2.1	1.5	10	7	.5	8.8	20	D196645
D196647	1.5	.4	300	1.8	2.2	10	5	B	12	15	D196647
D196648	3	.4	200	1.6	2.9	20	10	1	17	20	D196648
D196649	7	.8	200	.1L	5.4	30	10	B	75	70	D196649
D196650	1	.1L	200	1.8	.9	3	3	.3	6.2	15	D196650
D196651	10	.8	200	5.7	7.4	50	20	2	74	50	D196651
D196652	1.5	.8	300	3.8	1.5	10	5	.5	15	20	D196652
D196653	1.5	.5	200	1.6	1.2	7	5	.5	17	15	D196653
D196654	7	.1L	300	4.3	16	30	20	3	65	50	D196654
D196655	1.5	.1L	300	2.3	1.8	5	5	B	16	15	D196655
D196657	2	.7	150	2.4	1.4	7	7	.5	26	20	D196657

Table 5.--Major-, minor-, and trace-element compositon of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)	Sample number
D196658	4.7	1.1	1.2	0.63	0.031	0.21	1.6	0.16	N	19	D196658
D196659	1.5	.57	1.6	.53	.026	.089	.80	.040	N	10	D196659
D196661	1.5	.75	1.0	.39	.12	.044	8.5	.032	N	22	D196661
D196662	1.7	.83	1.1	.37	.53	.076	1.0	.039	N	8.4	D196662
D196624	3.4	1.1	.77	.42	.081	.28	.32	.052	N	8.9	D196624
D196625	1.2	.46	1.9	.52	.061	.044	.25	.038	N	2.2	D196625
D196627	7.4	1.1	1.4	.50	.041	.19	.79	.53	N	10	D196627
D196628	1.3	.61	1.6	.51	.029	.070	.65	.043	N	4.6	D196628
D196629	.97	.66	1.3	.41	.11	.035	.55	.031	N	15	D196629
D196630	.47	.36	1.1	.35	.14	.052	.64	.48	N	19	D196630
D196631	2.2	.76	1.3	.39	.49	.070	.28	.050	N	5.2	D196631
D196632	1.1	.54	1.2	.40	.57	.035	.46	.038	N	4.5	D196632
D196634	3.6	1.4	.73	.34	.50	.32	2.4	.077	N	63	D196634
D196635	1.6	.78	1.2	.40	.54	.056	.28	.047	N	6.3	D196635
D196637	2.5	1.0	1.6	.58	.11	.059	.90	.084	N	7.1	D196637
D196638	.97	.61	1.6	.49	.087	.043	.55	.031	N	6.6	D196638
D196640	1.2	.70	1.6	.47	.068	.050	.58	.036	N	1.6	D196640

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)	Sample number
D196658	150	1,000	1.5	0.23L	2.6	8.6	13	55	7	N	D196658
D196659	150	150	1	.13L	.9	6.2	7.1	25	3	N	D196659
D196661	70	500	3	.26L	2.3	4.5	4.2	20L	5	7	D196661
D196662	150	70	1.5	.13L	1.5	4.0	7.5	30	5	N	D196662
D196624	150	150	2	.14L	1.6	9.8	10	90	10	3L	D196624
D196625	150	100	.5	.11L	1.1	3.6	5.6	20	2	N	D196625
D196627	200	7,000	5	.29L	2.0	14	10	40	15	7L	D196627
D196628	200	200	.7	.12L	.8	3.7	4.4	20	3	N	D196628
D196629	150	100	1.5	.42	3.0	4.0	21	20	5	2L	D196629
D196630	200	2,000G	2	.13L	6.2	6.3	9.0	20	15	10	D196630
D196631	200	100	3	.12L	3.1	5.1	8.0	25	7	7	D196631
D196632	150	200	.3	.21	.5	3.0	4.1	25	2	N	D196632
D196634	150	150	1.5	.21L	28	29	25	110	15	7	D196634
D196635	100	300	.3	.11L	.7	3.3	4.4	35	3	N	D196635
D196637	150	150	.5	.18L	.6	6.3	13	20	5	3L	D196637
D196638	150	200	.3	.10L	.6	1.7	3.6	20	1.5	N	D196638
D196640	200	300	.3	.12L	3.5	2.8	4.2	25	2	2L	D196640

Table 5.--Major-, minor-, and trace-element compositon of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.--continued

Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sample number
D196658	0.12	N	9.4	42	3	5	5	40L	5.7L	3.6	D196658
D196659	.14	N	4.3	91	2	3	2	88	4.7	.4	D196659
D196661	.56	N	8.7	40	7	N	5	46L	7.9	1.5	D196661
D196662	.19	N	6.9	64	5	2L	2	45L	5.9	1.0	D196662
D196624	.06	N	5.9	41	3	3L	2	44L	5.8	1.9	D196624
D196625	.06	N	3.5	190	2	2L	1	260	3.7	.4	D196625
D196627	.18	N	12	52	3	7L	5	38L	7.2	2.0	D196627
D196628	.06	N	4.7	96	3	2L	1	84	4.2	.4	D196628
D196629	.23	N	5.4	77	7	2L	3	45	3.1	1.1	D196629
D196630	.10	N	1.3L	32	7	10	7	44L	3.1	4.7	D196630
D196631	.06	N	6.8	89	2	3	2	42L	6.0	1.1	D196631
D196632	.15	N	4.3	100	1.5	2	1	87	4.2	.4	D196632
D196634	1.2	N	6.8	62	15	10	50	47	9.6	7.3	D196634
D196635	.11	N	5.9	140	1	2L	1.5	44L	4.5	.4	D196635
D196637	.24	N	12	100	1.5	3L	1.5	46L	6.2	.8	D196637
D196638	.15	N	4.7	130	1.5	N	1.5	220	4.7	.6	D196638
D196640	.08	N	5.7	180	2	2L	2	390	3.0L	.3	D196640

Sample number	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D196658	3	1.3	200	3.7	5.2	15	15	1.5	39	50	D196658
D196659	2	.7	200	2.7	2.1	10	10	1	5.4	20	D196659
D196661	5	.9	300	2.5	1.8	7	7	B	130	50	D196661
D196662	2	.5	200	2.1	1.8	10	7	.7	5.5	20	D196662
D196624	7	.6	200	2.5	11	20	15	1.5	16	30	D196624
D196625	1.5	.7	200	2.4	.8	7	7	.5	6.0	15	D196625
D196627	10	1.2	500	5.3	9.8	30	30	2	25	100	D196627
D196628	2	.6	200	2.0	2.7	10	3	.3	6.5	20	D196628
D196629	2	.5	150	1.6	2.4	15	7	.7	83	15	D196629
D196630	3	.6	200	1.1	10	30	15	2	34	70	D196630
D196631	3	1.0	200	3.6	4.1	20	20	2	31	70	D196631
D196632	1	.7	200	1.8	.9	5	3	.3	19	15	D196632
D196634	7	1.1	200	5.7	13	70	20	3	170	70	D196634
D196635	1L	.7	200	2.3	.8	7	3	.3	29	15	D196635
D196637	3	1.6	300	4.4	4.3	15	10	.5	19	30	D196637
D196638	1L	.1L	200	1.4	.9	1.5	3	.2	5.0	10	D196638
D196640	1L	.6	200	1.8	1.2	3	3	.3	17	20	D196640

Table 6.--Elements looked for but not detected in lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dakota.

[Approximate lower detection limits for these elements in lignite ash, by the six-step spectrographic method of the U.S. Geological Survey are included]

Element Name	Symbol	Lower limit of detection (ppm) in lignite ash
Gold	Au	50
Bismuth	Bi	20
Cerium	Ce	500
Dysprosium	Dy	100
Erbium	Er	100
Europium	Eu	200
Gadolinium	Gd	100
Hafnium	Hf	200
Holmium	Ho	50
Indium	In	20
Lutetium	Lu	70
Neodymium	Nd	150
Palladium	Pd	5
Praseodymium	Pr	200
Platinum	Pt	100
Rhenium	Re	100
Samarium	Sm	200
Tin	Sn	20
Tantalum	Ta	1,000
Terbium	Tb	700
Tellurium	Te	5,000
Thallium	Tl	100
Thulium	Tm	50
Tungsten	W	200

Table 7.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion-temperature of 55 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.

[For comparison, geometric means for 32 other Fort Union region, North Dakota, and Montana lignite samples are included (Swanson and others, 1974, table 8). All values are in percent except Kcal/kg, Btu/lb, ash-fusion temperatures and geometric deviations and are reported on the as-received basis. L, less than the value shown. Leaders (---) indicate no data. Kcal/kg = 0.556(Btu/lb). $^{o}F = (^{o}C \times 1.8) + 32$]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Fort Union region geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	37.5	26.2	43.4	37.4	1.1	34.9
Volatile matter	25.0	13.3	38.8	24.7	1.2	27.4
Fixed carbon	27.9	20.5	44.0	27.6	1.2	30.1
Ash	9.5	3.6	23.7	8.8	1.5	6.4
Hydrogen	6.7	5.2	7.3	6.6	1.1	6.7
Carbon	36.8	28.6	41.9	36.6	1.1	40.7
Nitrogen	.6	.4	.7	.6	1.2	.6
Oxygen	44.7	29.7	51.5	44.5	1.1	43.9
Sulfur	1.2	.2	11.7	.8	2.4	.6
Heat of combustion						
Kcal/kg	3,410	2,690	3,865	3,395	1.1	3,770
Btu/lb	6,130	4,840	6,950	6,110	1.1	6,780
Forms of sulfur						
Sulfate	0.14	0.01L	.95	0.04	4.5	0.02
Pyritic	.77	.01L	8.40	.27	4.3	.13
Organic	.50	.13	2.46	.41	1.9	.36
Ash-fusion temperatures, ^{o}C						
Initial deformation	1,180	1,040	1,410	1,180	1.1	---
Softening temperature	1,215	1,060	1,460	1,210	1.1	---
Fluid temperature	1,260	1,080	1,590	1,260	1.1	---

Table 8.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of nine major and minor oxides in the laboratory ash of 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.

[For comparison, geometric means of analyses of 80 other Fort Union region, North Dakota and Montana lignite samples are included (Hatch and Swanson, 1977, table 5a). All samples were ashed at 525°C; all analyses except geometric deviation are in percent]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Fort Union region geometric mean
		Minimum	Maximum			
(Ash)	14.0	6.7	40.2	13.1	1.4	9.0
SiO_2	26	7.6	56	23	1.6	13
Al_2O_3	10	4.2	17	9.7	1.4	8.6
CaO	19	2.3	40	16	1.8	22
MgO	6.1	.95	12.4	5.55	1.5	7.01
Na_2O	3.4	.18	11.1	1.48	3.7	1.43
K_2O	.74	.20	3.0	.63	1.8	.059
Fe_2O_3	9.5	.65	53	7.0	2.2	5.0
TiO_2	.73	.10	6.4	.62	1.8	.49
SO_3	12	3.5	32	10	1.8	19

Table 9.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 35 elements in 57 lignite samples from the Fort Union Formation, McCone, Richland, Dawson, and Wibaux Counties, Mont., and Golden Valley County, N. Dak.

[For comparison, geometric means of analyses for 80 other Fort Union region North Dakota and Montana coal samples are included (Hatch and Swanson, 1977, table 5b). All analyses except geometric deviation are in percent or parts per million and are reported on a whole-coal basis. As, Co, Cr, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole coal. All other values were calculated from determinations made on coal ash. L, less than the value shown]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Fort Union region geometric mean
		Minimum	Maximum			
Si	1.8	0.27	8.2	1.4	2.0	0.55
Al	.76	.20	2.9	.67	1.7	.41
Ca	1.6	.66	2.4	1.5	1.4	1.4
Mg	.45	.23	.64	.44	1.3	.38
Na	.30	.013	.75	.14	3.4	.095
K	.09	.020	.68	.07	2.3	.006
Fe	1.0	.038	15	.64	2.7	.32
Ti	.06	.01	.53	.05	1.9	.028
			Parts per million			
As	15	0.7	180	6.2	3.8	4
B	150	50	200	100	1.5	100
Ba	500	20	7,000	200	3.5	300
Be	1	.3L	5	.7	2.8	.2
Co	.5	.03	7	.2	3.4	1.5
Cr	1	.1L	7	.5	3.1	1.5
Cu	7.9	2.2	30	6.7	1.8	3.8
F	41	20L	190	35	1.8	26
Ga	5	.7	20	3	2.1	1.5
Hg	.15	.02	1.23	.10	2.5	.09
Li	6.6	.8L	32	5.2	2.0	2.4
Mn	85	31	190	78	1.5	29
Mo	3	.5L	20	2	2.3	1
Nb	2	2L	10	1.5	2.3	1
Ni	3	.5	50	2	2.7	1.5
Pb	4.4	2.1	9.6	4	1.6	3.8
Sb	1.2	.1	11	.7	2.9	.2
Sc	2	.5	10	1.5	2.9	1.5
Se	.7	.1L	1.7	.6	1.6	.6
Sr	300	70	700	300	1.7	500
Th	2.3	.1L	5.7	1.9	1.8	2.4
U	3.4	.2L	17	2.3	2.4	.6
V	15	1.5	70	10	2.4	3
Y	7	1.5	30	7	2.1	3
Yb	.7	.15	3	.7	2.2	.2
Zn	22	2.5	170	11	3.2	2.3
Zr	20	2	100	20	2.3	10